US008091634B2

(12) **United States Patent**
Corre et al.

(10) **Patent No.: US 8,091,634 B2**
(45) **Date of Patent: Jan. 10, 2012**

(54) **SINGLE PACKER STRUCTURE WITH SENSORS**

(75) Inventors: **Pierre-Yves Corre**, Eu (FR); **Stephane Briquet**, Houston, TX (US); **Stephen Yeldell**, Sugar Land, TX (US); **Carsten Sonne**, Kota Kinabalu (MY); **Edward Harrigan**, Richmond, TX (US); **Alexander F. Zazovsky**, Houston, TX (US)

(73) Assignee: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 220 days.

(21) Appl. No.: **12/361,970**

(22) Filed: **Jan. 29, 2009**

(65) **Prior Publication Data**

US 2010/0122812 A1 May 20, 2010

Related U.S. Application Data

(60) Provisional application No. 61/116,442, filed on Nov. 20, 2008.

(51) **Int. Cl.**
E21B 49/10 (2006.01)

(52) **U.S. Cl.** **166/250.17**; 166/100

(58) **Field of Classification Search** 166/250.01, 166/264, 100, 101
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,441,894	A		5/1948	Mennecier
2,511,759	A		6/1950	Williams
2,581,070	A		1/1952	Blood
2,600,173	A		6/1952	Sewell et al.
2,623,594	A		12/1952	Sewell
2,675,080	A		4/1954	Williams
2,742,968	A		4/1956	Hildebrandt
2,842,210	A		7/1958	Ramsey
2,843,208	A		7/1958	Blood
2,905,247	A	*	9/1959	Vestermark 166/100
3,915,229	A		10/1975	Nicolas
3,926,254	A		12/1975	Evam et al.
4,236,113	A		11/1980	Wiley
4,500,095	A		2/1985	Schisler et al.
4,635,717	A		1/1987	Jageler
4,830,105	A		5/1989	Petermann
4,886,117	A		12/1989	Patel
4,923,007	A		5/1990	Sanford et al.
5,335,542	A	*	8/1994	Ramakrishnan et al. .. 73/152.08
5,358,039	A		10/1994	Fordham
5,361,836	A		11/1994	Sorem et al.
5,404,947	A		4/1995	Sorem et al.
5,439,053	A		8/1995	Eslinger et al.
5,549,159	A	*	8/1996	Shwe et al. 166/250.02
5,605,195	A		2/1997	Eslinger et al.

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0528327 2/1993

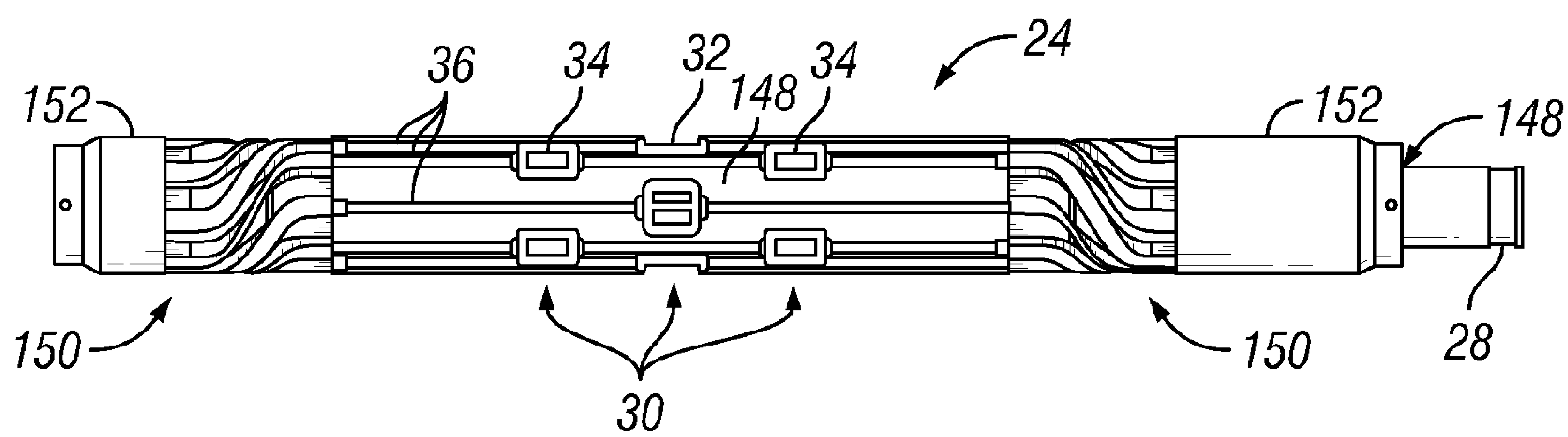
(Continued)

Primary Examiner — Jennifer H Gay
Assistant Examiner — Blake Michener
(74) *Attorney, Agent, or Firm* — David J Smith

(57) **ABSTRACT**

A technique involves collecting formation fluids through a single packer having at least one drain located within the single packer. The single packer is designed with an outer flexible skin and one or more drains coupled to the outer flexible skin. The single packer further comprises one or more sensors positioned to detect one or more specific parameters that may be related to well characteristics and/or single packer characteristics.

17 Claims, 9 Drawing Sheets



U.S. PATENT DOCUMENTS

5,613,555	A	3/1997	Sorem et al.	
5,687,795	A	11/1997	Patel et al.	
5,725,055	A *	3/1998	Schirmer et al.	166/264
6,050,131	A *	4/2000	Willauer	73/37
6,315,050	B2	11/2001	Vaynshteyn et al.	
6,513,600	B2	2/2003	Ross	
6,564,876	B2	5/2003	Vaynshteyn et al.	
6,729,399	B2 *	5/2004	Follini et al.	166/264
6,865,933	B1	3/2005	Einarson et al.	
6,938,698	B2	9/2005	Coronado	
7,699,124	B2 *	4/2010	Corre et al.	175/60
2002/0014339	A1	2/2002	Ross	
2002/0017386	A1	2/2002	Ringgenberg et al.	
2002/0046835	A1	4/2002	Lee et al.	
2004/0099443	A1	5/2004	Meister et al.	
2004/0173363	A1	9/2004	Navarro-Sorroche	
2006/0042793	A1 *	3/2006	Del Campo et al.	166/264
2007/0215348	A1 *	9/2007	Corre et al.	166/264
2008/0115575	A1 *	5/2008	Meek et al.	73/152.24
2008/0125335	A1	5/2008	Bhavsar	
2008/0156487	A1	7/2008	Zazovsky et al.	
2009/0008079	A1 *	1/2009	Zazovsky et al.	166/60
2009/0159278	A1 *	6/2009	Corre et al.	166/264
2009/0211756	A1 *	8/2009	Goodwin et al.	166/264
2009/0301635	A1 *	12/2009	Corre et al.	156/84
2009/0308604	A1 *	12/2009	Corre et al.	166/250.17
2010/0071898	A1 *	3/2010	Corre et al.	166/264

FOREIGN PATENT DOCUMENTS

EP	0528328	2/1993
EP	0702747	3/1996
WO	03/018956	3/2003

* cited by examiner

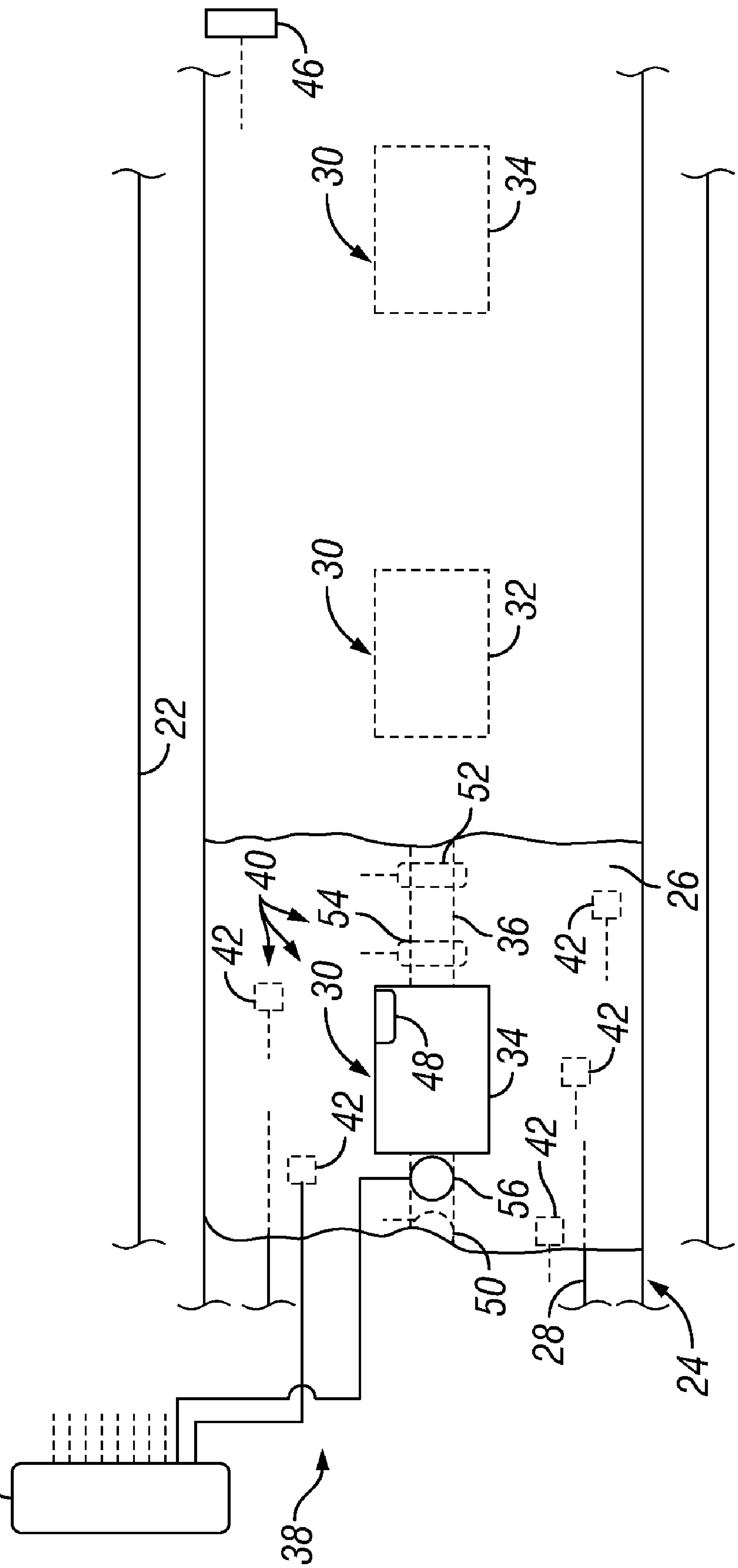

46
30
34
30
32
22
52
40
54
26
36
42
30
42
42
48
34
42
42
56
42
20
50
28
24
44
38

FIG. 1

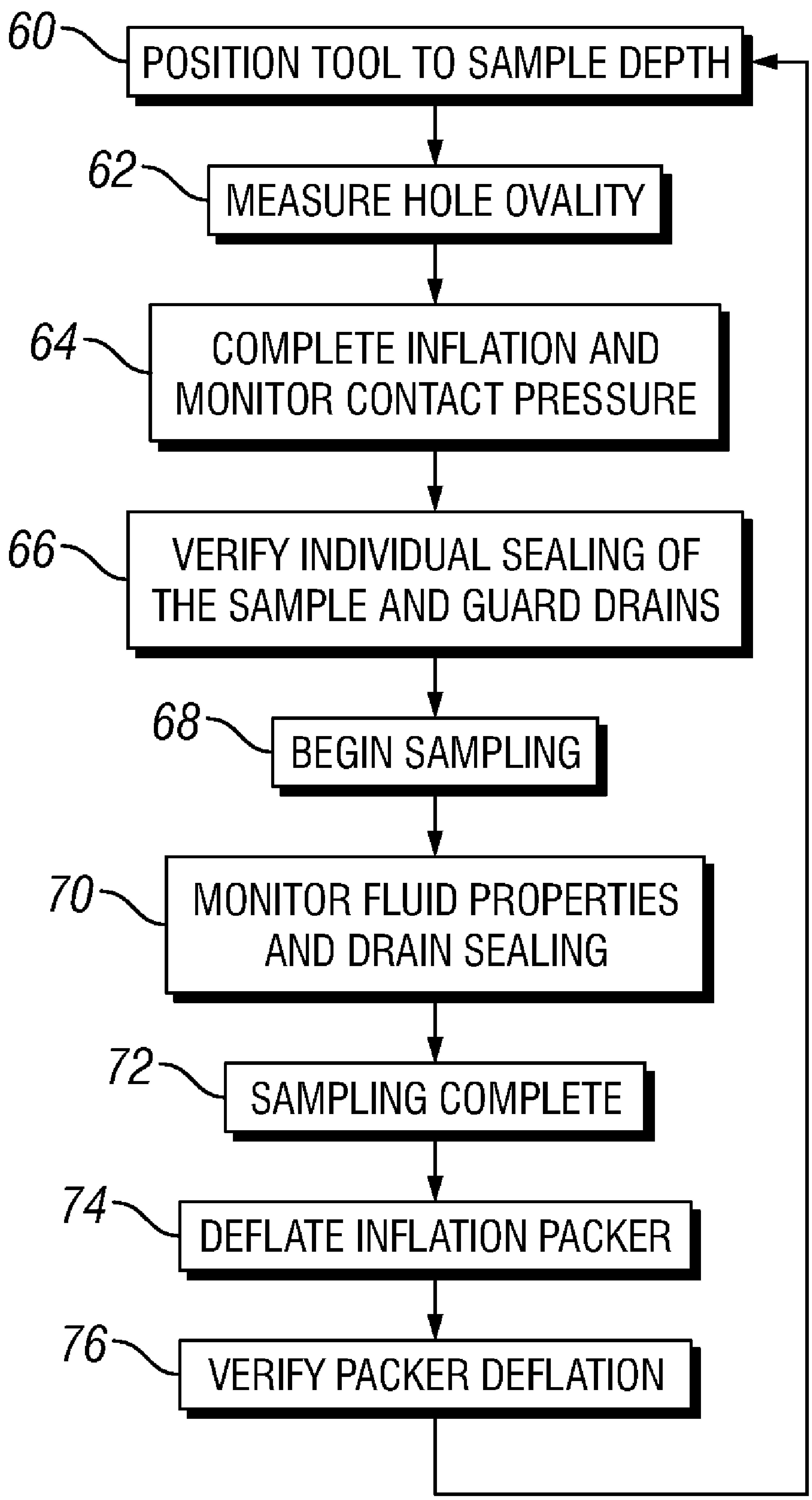

60
POSITION TOOL TO SAMPLE DEPTH
62
MEASURE HOLE OVALITY
64
COMPLETE INFLATION AND MONITOR CONTACT PRESSURE
66
VERIFY INDIVIDUAL SEALING OF THE SAMPLE AND GUARD DRAINS
68
BEGIN SAMPLING
70
MONITOR FLUID PROPERTIES AND DRAIN SEALING
72
SAMPLING COMPLETE
74
DEFLATE INFLATION PACKER
76
VERIFY PACKER DEFLATION

FIG. 2

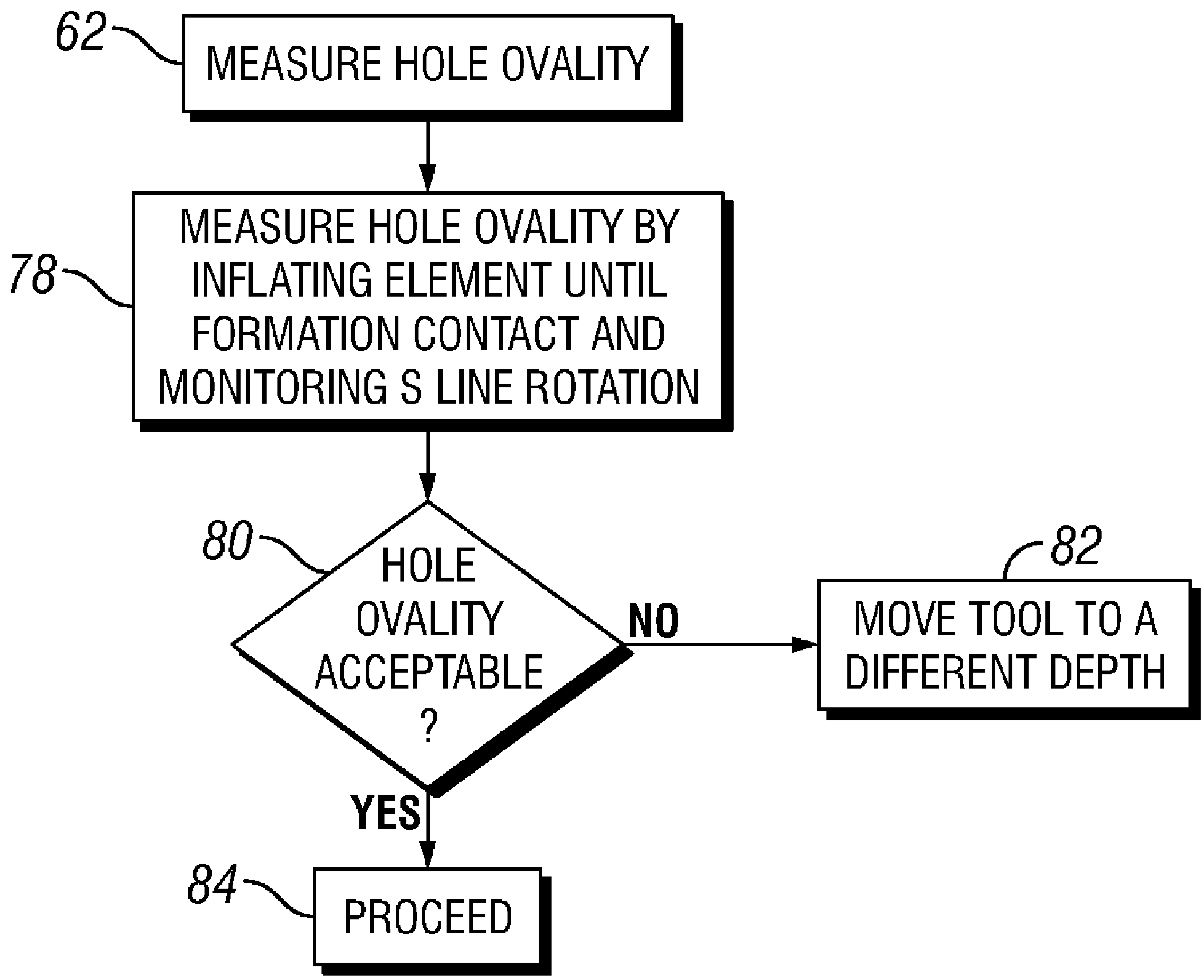

62
MEASURE HOLE OVALITY
78
MEASURE HOLE OVALITY BY INFLATING ELEMENT UNTIL FORMATION CONTACT AND MONITORING S LINE ROTATION
80
HOLE OVALITY ACCEPTABLE ?
NO
82
MOVE TOOL TO A DIFFERENT DEPTH
YES
84
PROCEED

FIG. 3

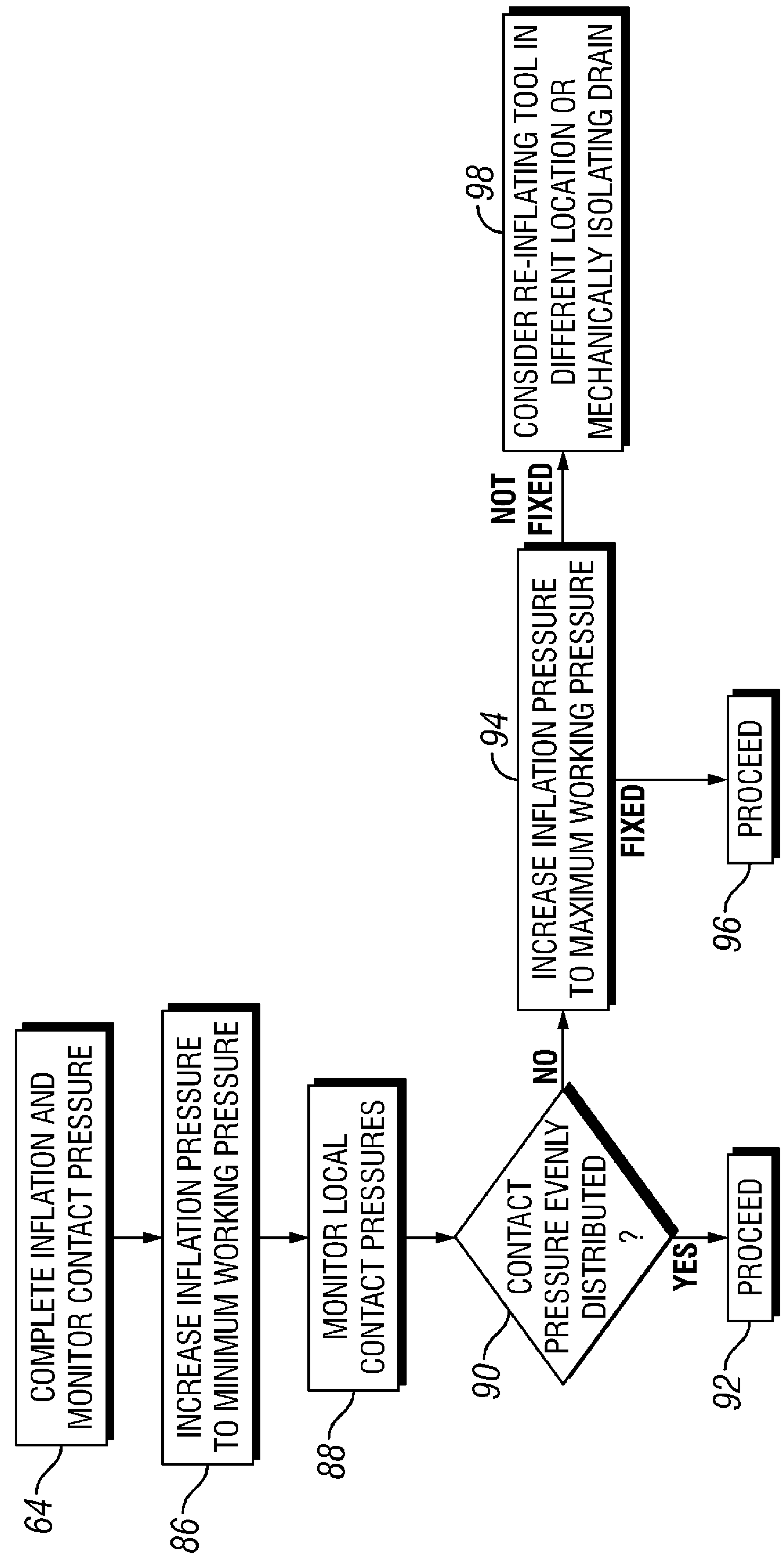

64
COMPLETE INFLATION AND MONITOR CONTACT PRESSURE
86
INCREASE INFLATION PRESSURE TO MINIMUM WORKING PRESSURE
88
MONITOR LOCAL CONTACT PRESSURES
90
CONTACT PRESSURE EVENLY DISTRIBUTED ?
YES
92
PROCEED
NO
94
INCREASE INFLATION PRESSURE TO MAXIMUM WORKING PRESSURE
FIXED
96
PROCEED
NOT FIXED
98
CONSIDER RE-INFLATING TOOL IN DIFFERENT LOCATION OR MECHANICALLY ISOLATING DRAIN

FIG. 4

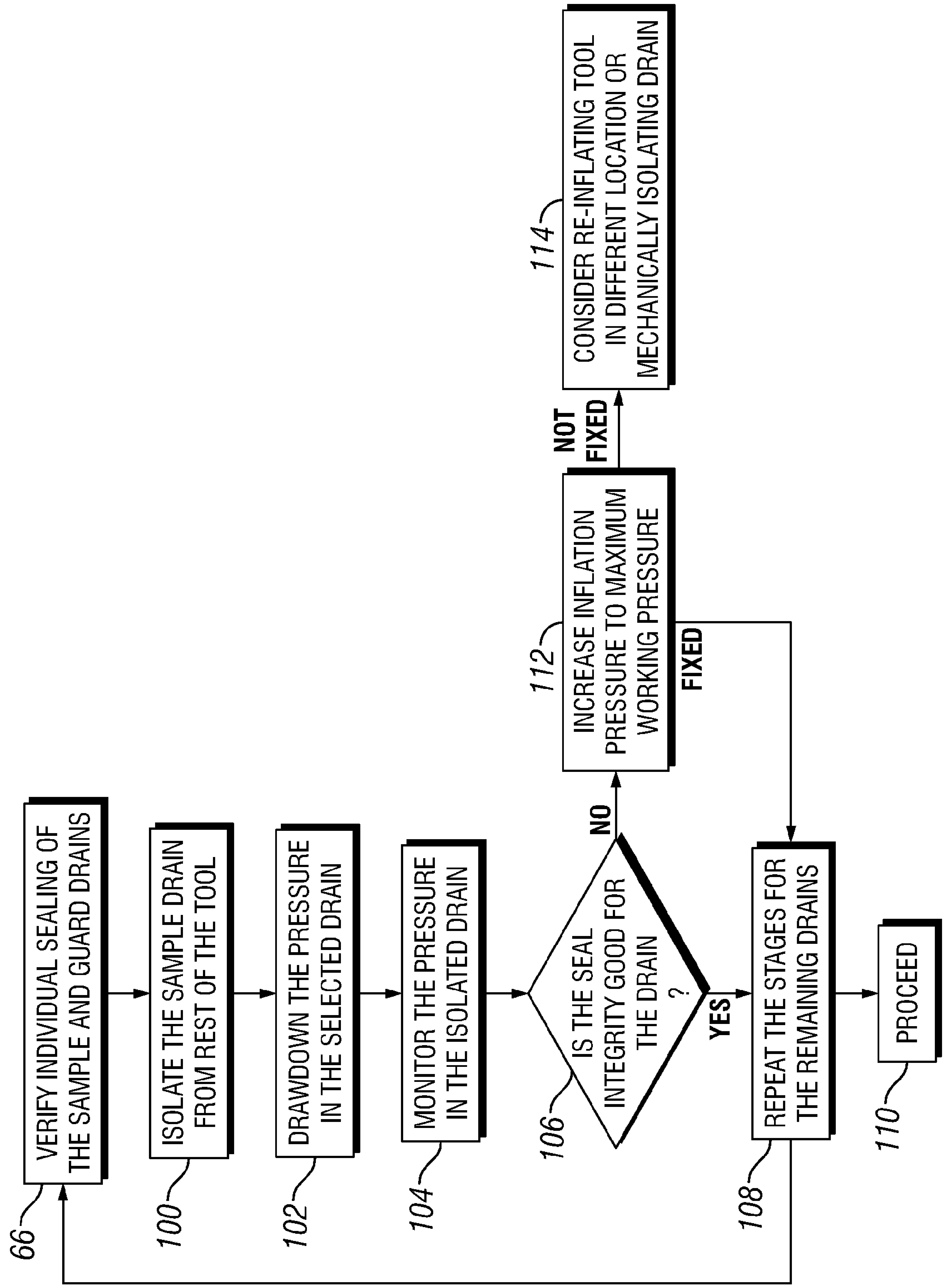

66
VERIFY INDIVIDUAL SEALING OF THE SAMPLE AND GUARD DRAINS
100
ISOLATE THE SAMPLE DRAIN FROM REST OF THE TOOL
102
DRAWDOWN THE PRESSURE IN THE SELECTED DRAIN
104
MONITOR THE PRESSURE IN THE ISOLATED DRAIN
106
IS THE SEAL INTEGRITY GOOD FOR THE DRAIN ?
NO
YES
112
INCREASE INFLATION PRESSURE TO MAXIMUM WORKING PRESSURE
NOT FIXED
FIXED
114
CONSIDER RE-INFLATING TOOL IN DIFFERENT LOCATION OR MECHANICALLY ISOLATING DRAIN
108
REPEAT THE STAGES FOR THE REMAINING DRAINS
110
PROCEED

FIG. 5

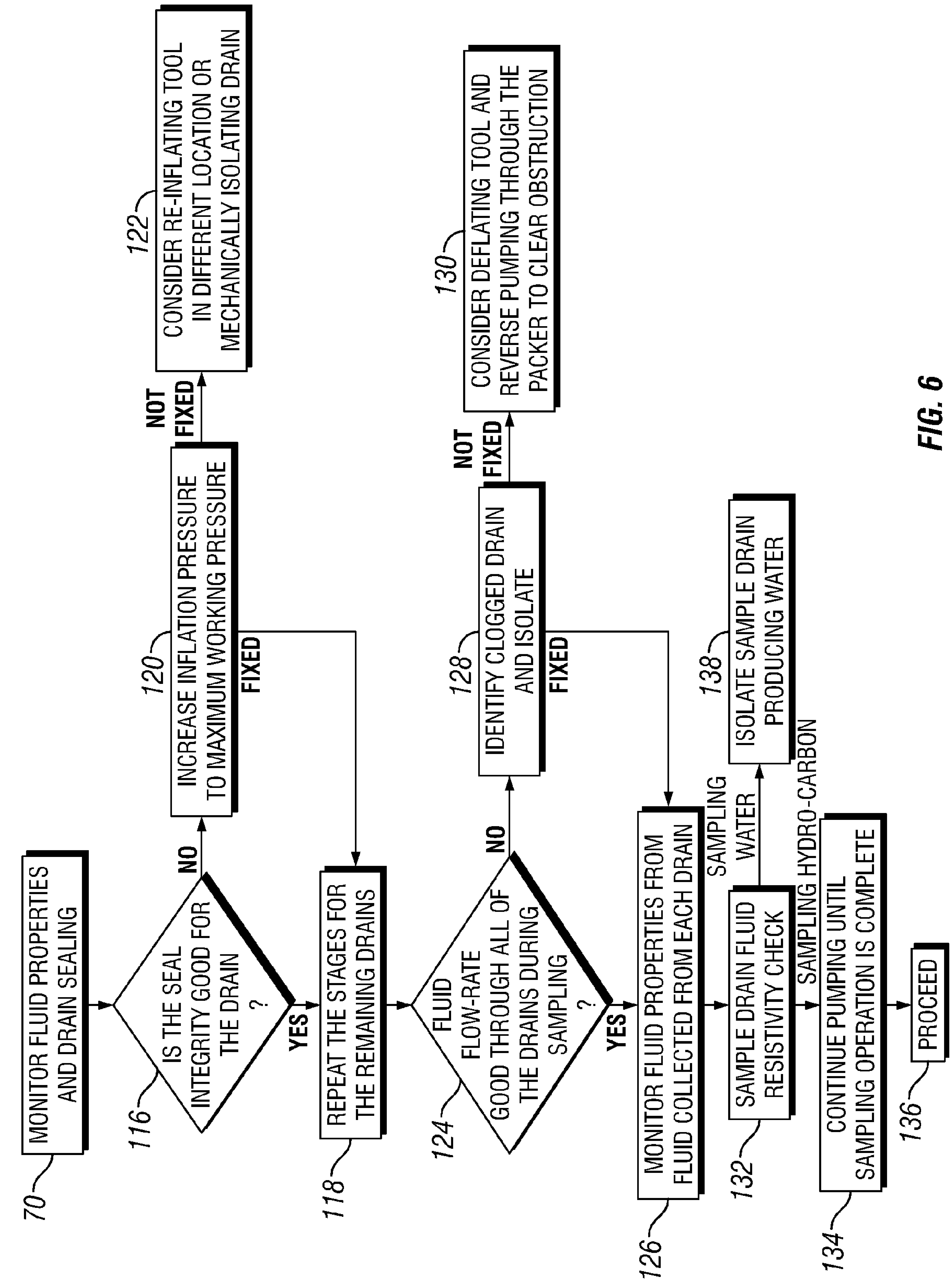

70
MONITOR FLUID PROPERTIES AND DRAIN SEALING
116
IS THE SEAL INTEGRITY GOOD FOR THE DRAIN ?
NO
120
INCREASE INFLATION PRESSURE TO MAXIMUM WORKING PRESSURE
NOT FIXED
122
CONSIDER RE-INFLATING TOOL IN DIFFERENT LOCATION OR MECHANICALLY ISOLATING DRAIN
FIXED
YES
118
REPEAT THE STAGES FOR THE REMAINING DRAINS
124
FLUID FLOW-RATE GOOD THROUGH ALL OF THE DRAINS DURING SAMPLING ?
NO
128
IDENTIFY CLOGGED DRAIN AND ISOLATE
NOT FIXED
130
CONSIDER DEFLATING TOOL AND REVERSE PUMPING THROUGH THE PACKER TO CLEAR OBSTRUCTION
FIXED
YES
126
MONITOR FLUID PROPERTIES FROM FLUID COLLECTED FROM EACH DRAIN
132
SAMPLE DRAIN FLUID RESISTIVITY CHECK
SAMPLING WATER
138
ISOLATE SAMPLE DRAIN PRODUCING WATER
SAMPLING HYDRO-CARBON
134
CONTINUE PUMPING UNTIL SAMPLING OPERATION IS COMPLETE
136
PROCEED

FIG. 6

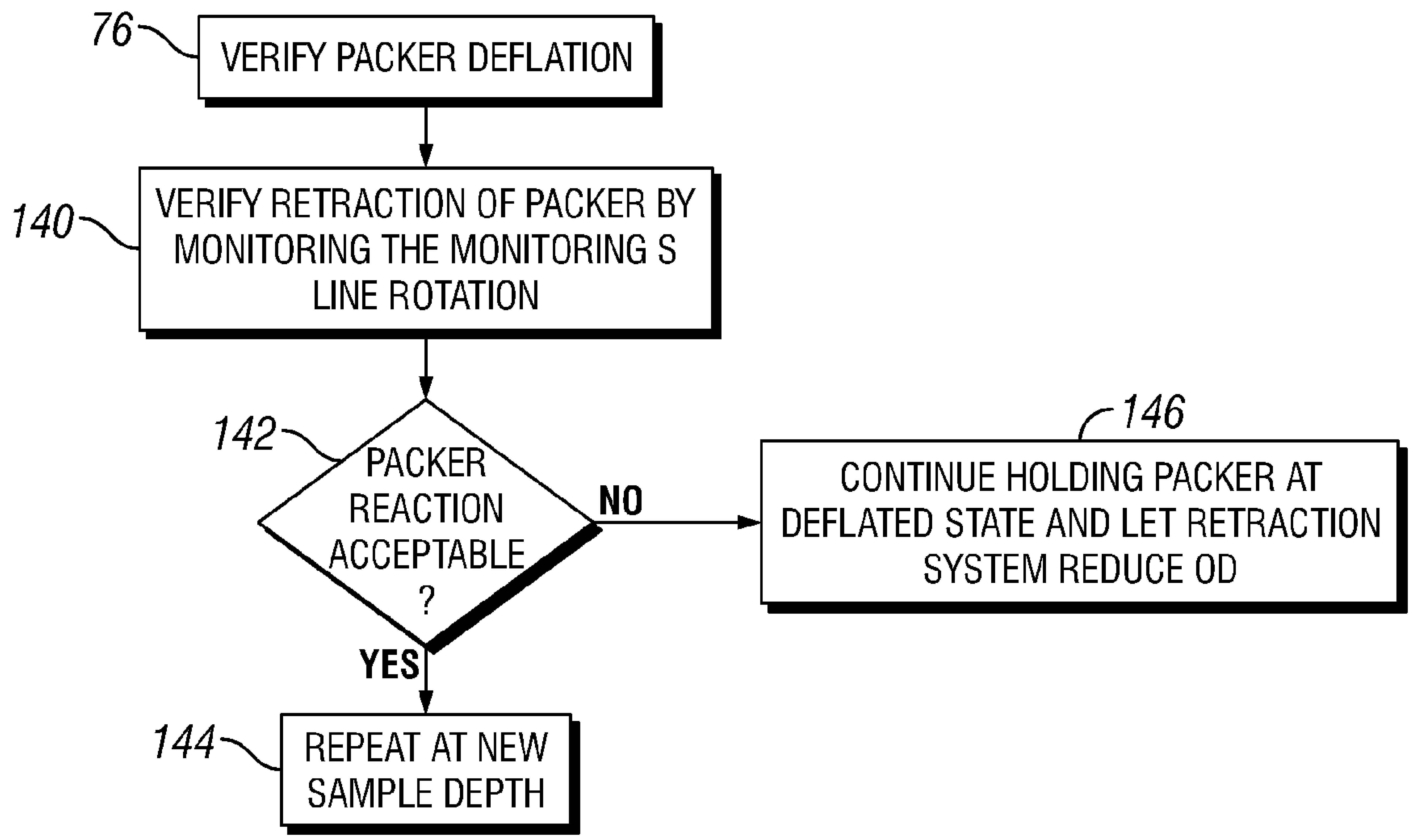


FIG. 7

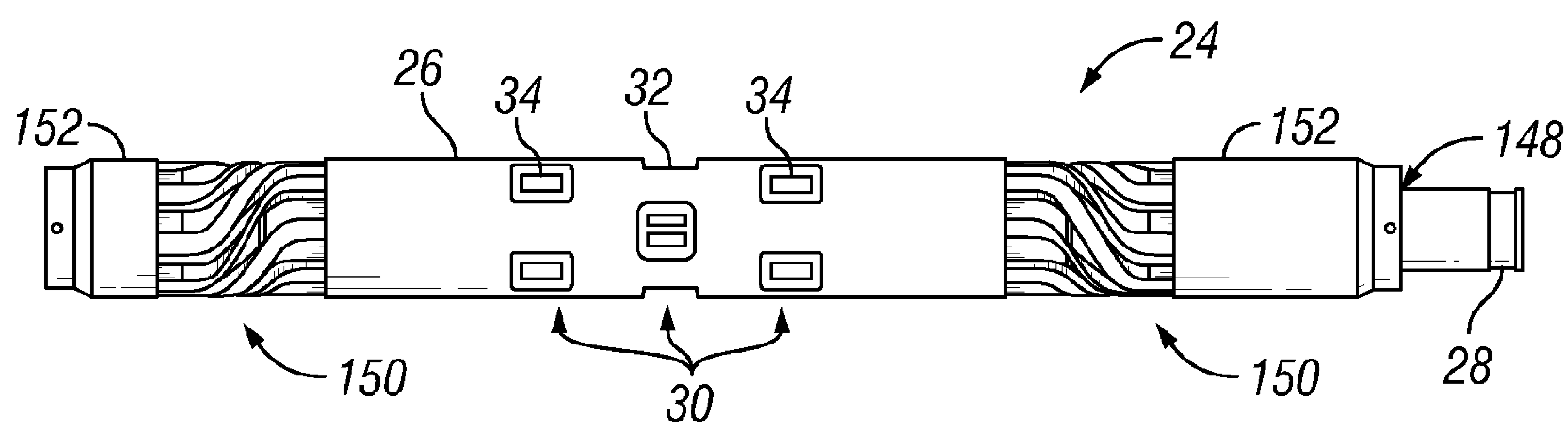


FIG. 8

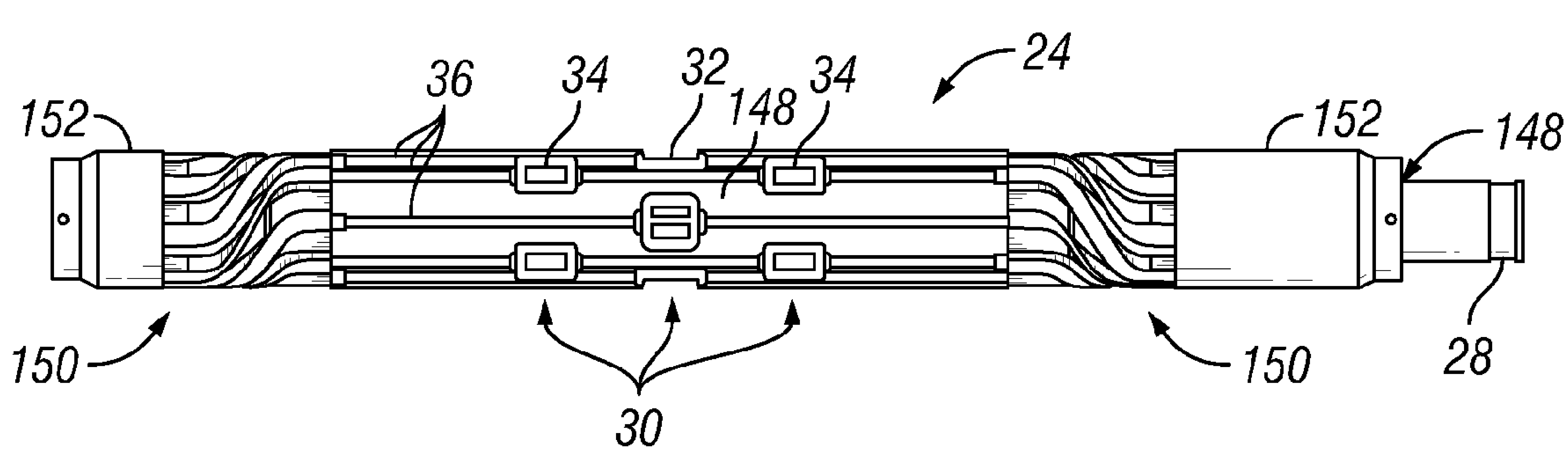


FIG. 9

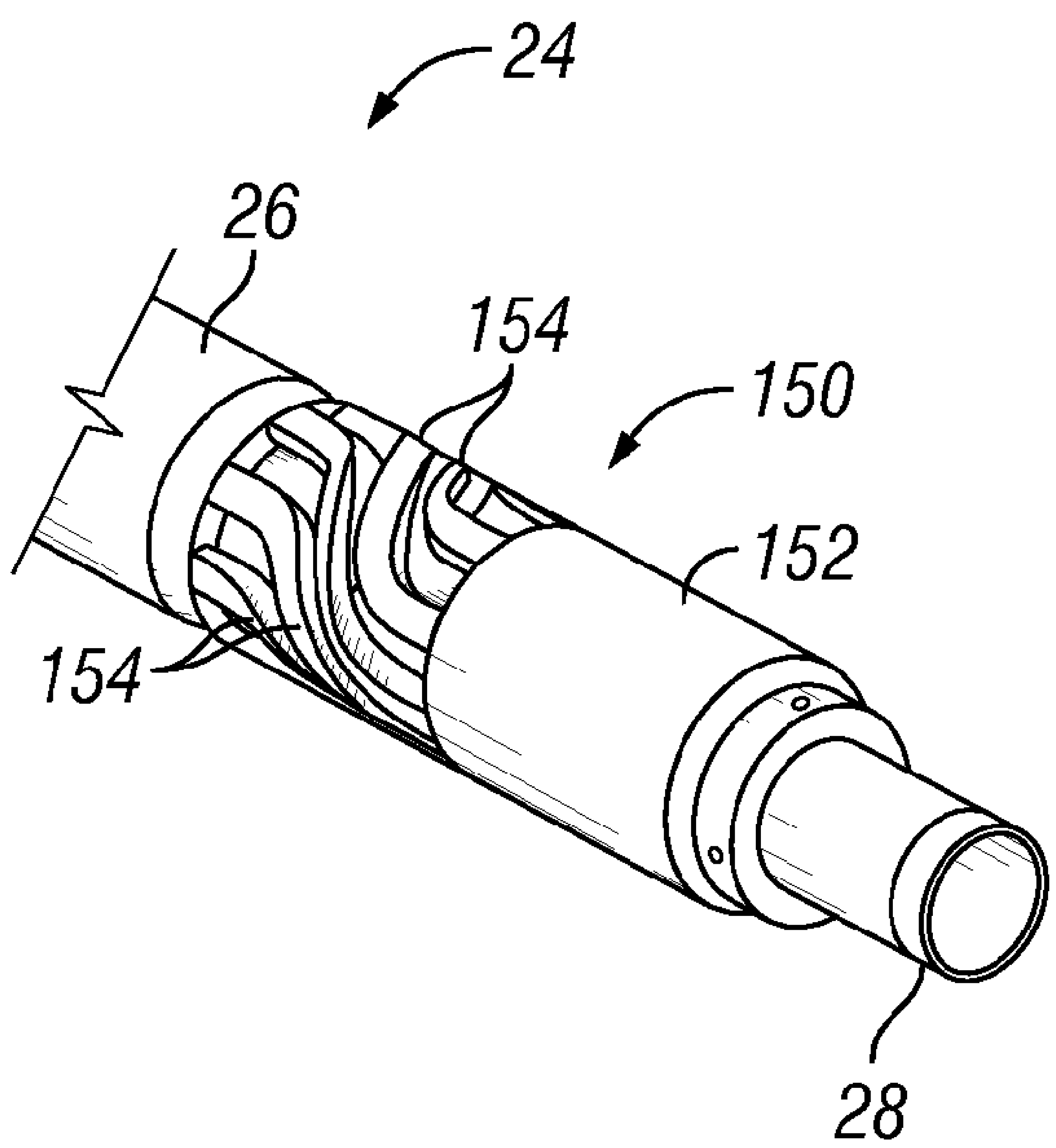


FIG. 10

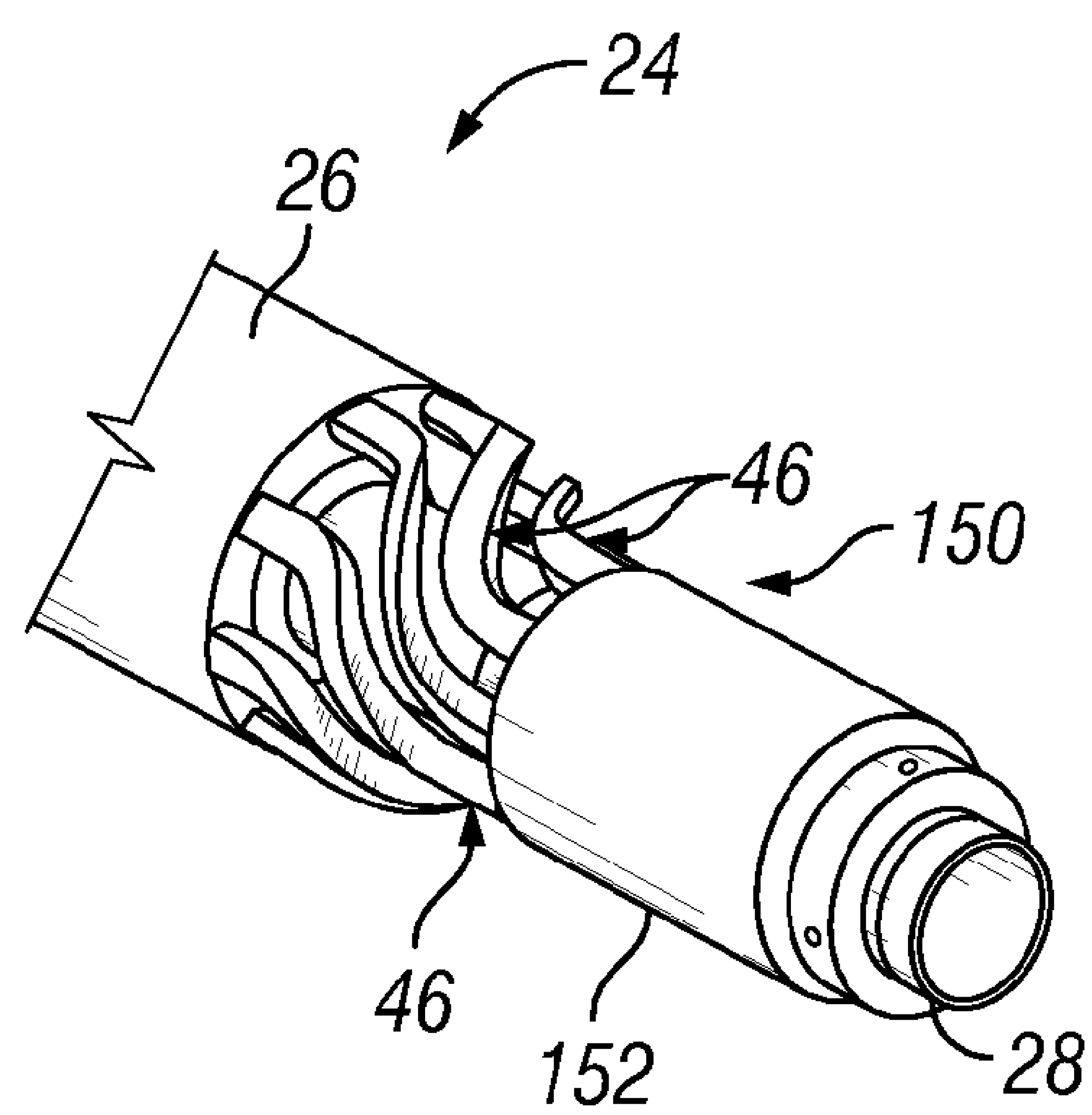


FIG. 11

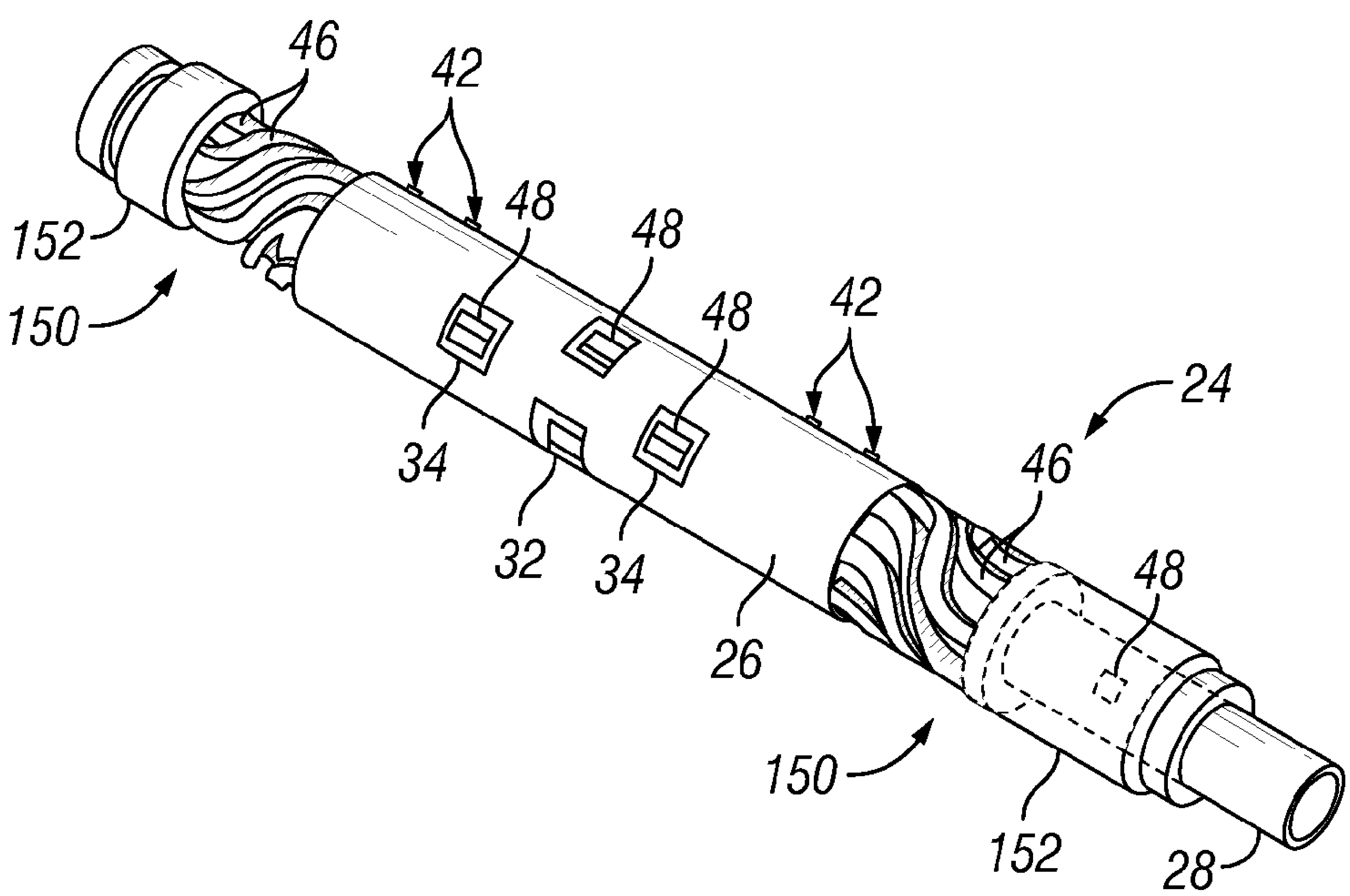


FIG. 12

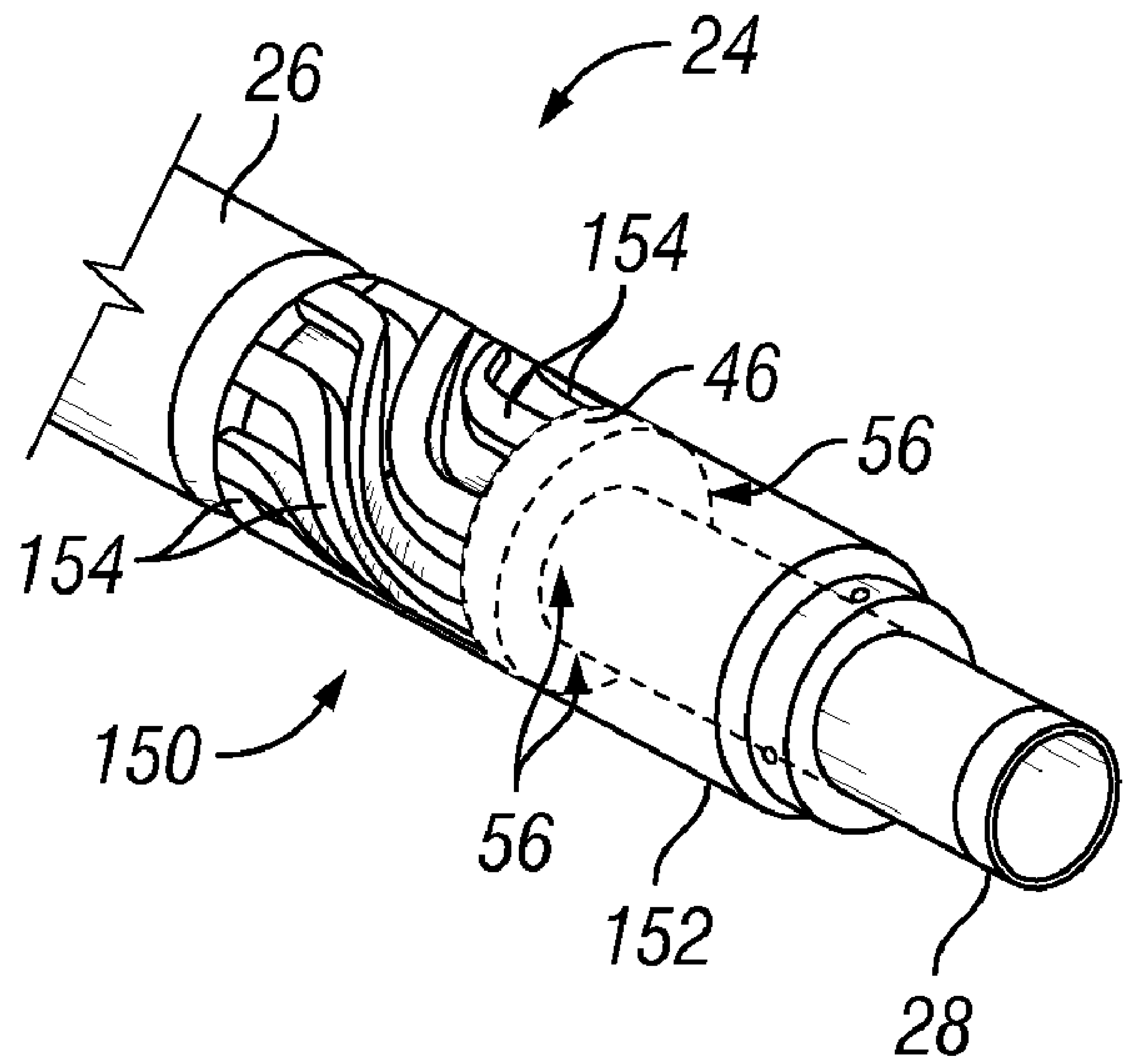

24
26
154
46
56
154
150
56
152
28

FIG. 13

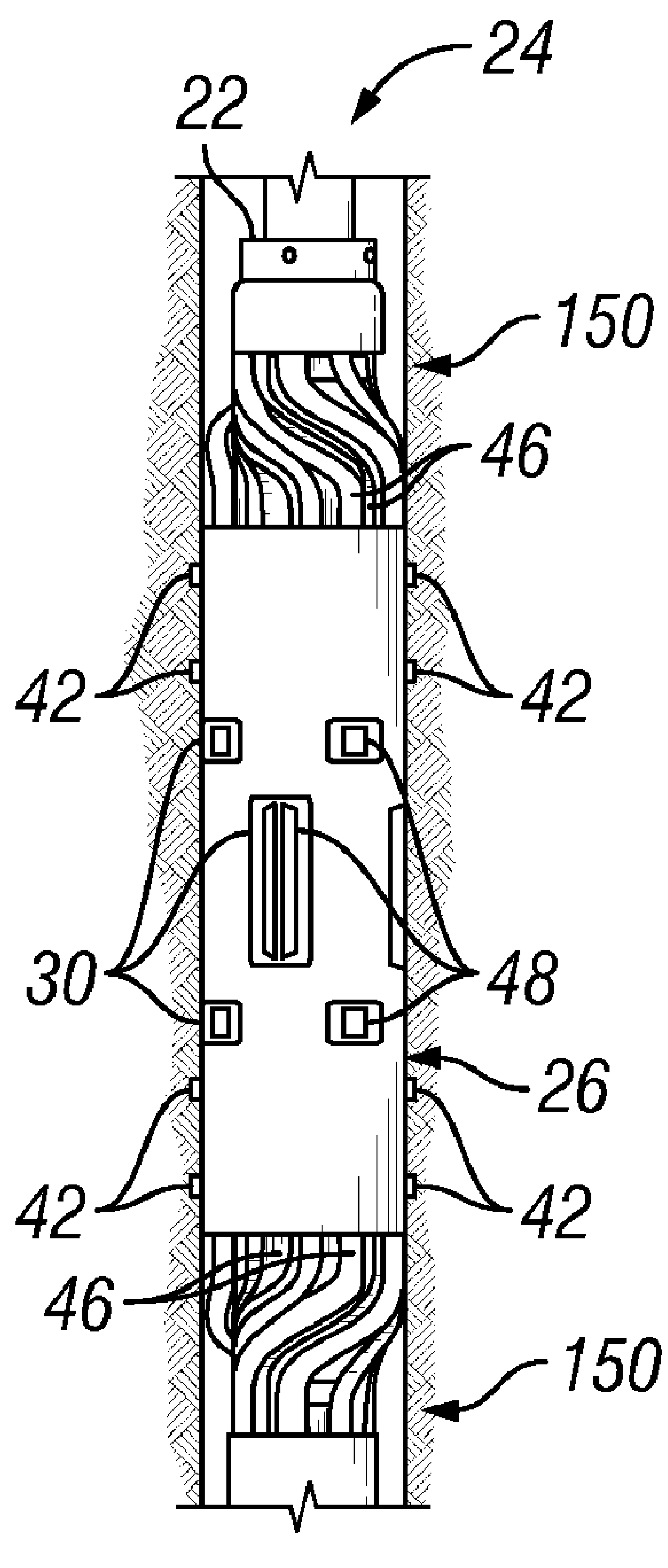

24
22
150
46
42
42
30
48
26
42
42
46
150

FIG. 14

SINGLE PACKER STRUCTURE WITH SENSORS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 61/116,442, filed on Nov. 20, 2008, which is incorporated herein by reference.

BACKGROUND

Packers are used in wellbores to isolate specific wellbore regions. A packer is delivered downhole on a conveyance and expanded against the surrounding wellbore wall to isolate a region of the wellbore. Two or more packers can be used to isolate one or more regions in a variety of well related applications, including production applications, service applications and testing applications.

In some applications, straddle packers are used to isolate specific regions of the wellbore to allow collection of fluid samples. However, straddle packers employ a dual packer configuration in which fluids are collected between two separate packers. Existing designs often do not provide an operator with sufficient information regarding downhole parameters. Additionally, the straddle packer configuration is susceptible to mechanical stresses which limit the expansion ratio and the drawdown pressure differential that can be employed. Other multiple packer techniques can be expensive and present additional difficulties in collecting samples and managing fluid flow in the wellbore environment.

SUMMARY

In general, the present invention provides a system and method for collecting formation fluids through a single packer having at least one drain located within the single packer. The single packer is designed with an outer flexible skin and one or more drains coupled to the outer flexible skin. The single packer further comprises one or more sensors positioned to detect one or more specific parameters.

BRIEF DESCRIPTION OF THE DRAWINGS

Certain embodiments of the invention will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements, and:

FIG. **1** is a schematic view of a portion of a single packer positioned in a wellbore, according to an embodiment of the present invention;

FIG. **2** is a flow chart illustrating one procedural example for using the single packer, according to an embodiment of the present invention;

FIG. **3** is a flow chart illustrating a portion of the procedural example of FIG. **2**, according to an embodiment of the present invention;

FIG. **4** is a flow chart illustrating another portion of the procedural example of FIG. **2**, according to an embodiment of the present invention;

FIG. **5** is a flow chart illustrating another portion of the procedural example of FIG. **2**, according to an embodiment of the present invention;

FIG. **6** is a flow chart illustrating another portion of the procedural example of FIG. **2**, according to an embodiment of the present invention;

FIG. **7** is a flow chart illustrating another portion of the procedural example of FIG. **2**, according to an embodiment of the present invention;

FIG. **8** is a front elevation view of one example of the single packer, according to an embodiment of the present invention;

FIG. **9** is a broken away view of the packer illustrated in FIG. **8** to further illustrate internal components of the single packer, according to an embodiment of the present invention;

FIG. **10** is a view of one end of the packer illustrated in FIG. **8** when in a contracted configuration, according to an embodiment of the present invention;

FIG. **11** is a view of one end of the packer illustrated in FIG. **8** when in an expanded configuration, according to an embodiment of the present invention;

FIG. **12** is a view of the single packer illustrating examples of sensors that can be incorporated into the single packer, according to an embodiment of the present invention;

FIG. **13** is a view of the single packer illustrating examples of valves that can be incorporated into the single packer, according to an embodiment of the present invention; and

FIG. **14** is a view of the single packer expanded against a surrounding formation, according to an embodiment of the present invention.

DETAILED DESCRIPTION

In the following description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those of ordinary skill in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

The present invention generally relates to a system and method for collecting formation fluids through one or more drains located in a packer, such as a single packer. Use of the single packer enables larger expansion ratios and higher drawdown pressure differentials. Additionally, the single packer configuration reduces the stresses otherwise incurred by the packer tool mandrel due to the differential pressures. In at least some embodiments, the single packer also is better able to support the formation in a produced zone at which formation fluids are collected. This quality facilitates relatively large amplitude draw-downs even in weak, unconsolidated formations.

The single packer expands across an expansion zone, and formation fluids can be collected from the middle of the expansion zone, i.e. between axial ends of the single packer. The formation fluid is collected and directed along flow lines, e.g. along flow tubes, from the one or more drains. For example, separate drains can be disposed along the length of the packer to establish collection intervals or zones that enable focused sampling at a plurality of collecting intervals, e.g. two or three collecting intervals. Separate flowlines can be connected to different drains, e.g. sampling drains and guard drains, to enable the collection of unique formation fluid samples.

The single packer provides a simplified packer structure that facilitates, for example, focused sampling. In one embodiment, one or more sensors are positioned along the single packer to monitor desired parameters. By way of example, the parameters may be related to well characteristics, including characteristics of flowing fluid, and/or to actuation of the single packer. In some applications, sensors can be incorporated into an outer flexible layer, e.g. an outer rubber layer. The outer flexible layer also may be used to contain drains, such as groups of drains in which a middle group comprises sampling drains and two axially outer groups comprise guard drains. The drains may be coupled to the flowlines in a manner that facilitates expansion and contraction of the single packer.

According to one embodiment, the present system and methodology generally relate to an instrumented packer assembly and methods for setting instrumentation into the packer assembly. The instrumentation may comprise one or more sensors designed to detect, measure and/or monitor downhole parameters. As described below, the sensors can be used with a single packer assembly to facilitate monitoring and operation of the packer assembly. The packer assembly, for example, enables placement of sensors to measure the packer expansion ratio and/or other measurements related to actuation of the packer. This allows for better control over operation of the packer. In some applications, measurements obtained downhole via packer sensors also can provide an indication of the level of stress applied to the packer. The sensors can further be used to measure well related parameters, such as fluid properties of fluids entering the packer during sampling procedures.

Referring generally to FIG. **1**, one embodiment of a packer assembly **20** is illustrated as deployed in a wellbore **22**. In this embodiment, the packer assembly **20** comprises an inflatable single packer **24** having an outer flexible skin **26** formed of expandable material, e.g. a rubber material, which allows for inflation of the packer **24**. The outer flexible skin **26** is mounted around a packer mandrel **28**, and comprises openings for receiving drains **30**. By way of example, drains **30** may comprise one or more sampling drains **32** positioned between guard drains **34**. The drains **30** are connected to corresponding flow lines **36** for transferring fluid received through the corresponding drains **30**. The flow lines **36** connected to guard drains **34** may be separated from the flow lines connected to sample drains **32**.

In the example illustrated in FIG. **1**, single packer **24** further comprises a sensor system **38** having a plurality of sensors **40**. By way of example, sensors **40** may comprise embedded sensors **42** that are embedded in outer flexible skin **26**. In some applications, embedded sensors **42** are pressure sensors able to measure contact pressure exerted by outer flexible skin **26** against the surrounding wall, e.g. the wellbore wall. The pressure sensors may be formed as an array of mechanical or solid-state contact pressure sensors that provide local contact pressure information. Data on the local contact pressure may be particularly useful in applications where the formation has many smaller washouts that can cause compromised sealing with respect to one or more of the drains **30**.

Data from the various sensors **40** is directed to a data acquisition system **44** which may be in the form of a computer based control system. With respect to the array off pressure sensors **42**, the data acquisition system **44** may be employed to sample and store output from each sensor **42** during inflation of packer **24**. The sensors may be numbered so the position of each sensor is known to the data acquisition system **44**. As the output of each sensor **42** is sampled, the output is converted to contact pressure by data acquisition system **44**. The local contact pressure is then compared to a global contact pressure predicted from the inflation pressure used to inflate packer **24**. If one or more local pressure sensors **42** registers contact pressure that is significantly lower than the determined global contact pressure, an operator is better able to decide whether to move the entire packer **24** to a better position or to shut off one or more specific drains **30**.

In an alternative approach, an average contact pressure based on data from local pressure sensors **42** can be determined. The average contact pressure is compared to the output of each sensor **42** to provide an indication of sealing integrity. The local contact pressures also can be used to prevent damage to the surrounding formation due to excessive pressure between the packer and the formation.

The plurality of sensors **40** also may comprise a variety of other types of sensors. For example, sensors **40** may comprise one or more extensometers **46** designed to detect and measure expansion of packer **24**. Depending on the specific design of packer **24**, the configuration of extensometers **46** can be selected to measure the expansion ratio of packer **24** via various techniques. By tracking expansion of packer **24**, an operator is able to determine both the expansion ratio and whether the packer is or has been efficiently inflated. The sensors **46** also can be used to determine ovality and to control other operational parameters, such as ensuring full inflation while minimizing or optimizing inflation pressure. When sufficient pressure is applied to fully inflate packer **24**, the extent of packer expansion can be measured by sensors **46** to determine whether full inflation has actually occurred. The extensometers **46** also may be used to provide measurements related to the deformation of outer flexible skin **26**. Such information can be valuable in determining the integrity of or damage to inflatable packer **24**. The information also can be valuable in determining the diameter of the outer flexible skin and thus the diameter of the borehole which is useful in providing job quality control, e.g. proper inflation, optimal tool selection, and washout detection. Data from extensometers **46** is delivered to data acquisition system **44** for appropriate processing.

In addition to the packer actuation sensors, e.g. sensors **42**, **46**, sensors **40** also may comprise sensors for measuring well related properties/characteristics. For example, sensors **40** may comprise one or more fluid property sensors **48**, such as temperature sensors. When fluid property sensors **48** comprise temperature sensors, the temperature sensors can be used within packer **24** for quality control. For example, temperature sensors **48** are useful in very low or very high temperature wells in which the properties of the outer flexible skin **26** are affected and can inhibit optimal operation of packer **24**. For example, temperature can affect the ability of outer flexible skin **26** to form adequate seals, and temperature also can render the outer flexible skin more sensitive to extrusion and deformation and thus a decreased lifetime. If the information is obtained and relayed from sensors **48** to data acquisition system **44**, the information can be used to predict the number of stations at which inflatable packer **24** is likely to perform in the given conditions.

The fluid property sensors **48** may be located within one or more of the sampling drains **32** and guard drains **34**. In some applications, for example, fluid property sensors **48** comprise formation pressure sensors installed within each sample drain **32** and guard drain **34**. By way of example, the formation pressure sensors may be mounted on an opposite side of the flow line **36** for each sample drain and may be mounted perpendicular to the flow line **36** for each guard drain.

When fluid property sensors **48** comprise pressure sensors within each drain **30**, the sensors **48** may be used for a variety of purposes. For example, the sensors **48** may be used to detect leaks and/or plugging prior to formation testing measurements. When formation pressure sensors are used to monitor for leaks, the output from each sensor **48** can be compared to the wellbore pressure. In the event pressure is registered by sensors **48** as on par with the wellbore pressure during a drawdown, an operator is able to determine that either the sealing has been compromised or a flow line **36** is plugged. Also, if the pressure sensors **48** have sufficiently high resolution, individual sensors can be used to take pretest measurements in the formation and can further be used in performing transient pressure build up measurements. However, application of these various techniques depends on the degree of isolation with respect to guard drains and sample drains.

Fluid property sensors **48** may be positioned within drains **30** or at other suitable locations, such as within flow lines **36** and/or in collectors at the axial ends of packer **24**. The fluid property sensors are extremely useful in providing direct measurements of fluid properties close to the formation. For example, sensors **48** can be used to measure temperature, viscosity, velocity, pressure, or other fluid parameters at each drain **30**. The data enables numerous evaluations, including verification of sealing by detecting clean/dirty fluid. The data also can provide an indication as to whether flow lines are plugged, leaking, or incurring other types of problems.

In many applications, sensors **40** also may comprise one or more pressure gauges **50** deployed in flow lines **36**. Additionally, sensors **40** may comprise one or more sensor cells **52** positioned at suitable locations, e.g. within flow lines **36**, to measure density, resistivity, viscosity, and other parameters of the fluid flowing into packer **24**. Resistivity measurements can be used for obtaining data related to clean-up time and sample assurance during a sampling operation. Additionally, sensors **40** may comprise one or more flow meters **54** that can be used to measure flow rates within flow lines **36** or at other locations within packer **24**.

The sensors **40** may be positioned at a variety of locations depending on the parameters measured and depending on the durability of the sensor. For example, sensors can be located within collectors at the end of the packer instead of in drains **30** to improve reliability. Additionally, sensors can be mounted in front of each flow line entrance for individual measurements or inside flow line collectors to obtain average measurements.

By positioning one or more sensors **40** on and/or in inflatable packer **24**, the sensors are useful for detecting many operational parameters. For example, the sensors **40** can be used individually or in cooperation to detect packer inflation, an opening of a first flow line **36**, a drawdown pressure initiated, an opening of a subsequent flow line, an occurrence of a leak, a shut down of flow lines upon leak detection, selected fluid properties, and a variety of other parameters and operational events.

Control over flow through individual flow lines **36** can be achieved by placing valves **56** in desired flow lines **36**. The valves **56** are used to open or shut down individual flow lines upon the occurrence of specific events, such as leakage proximate a given drain **30**. The control system/data acquisition system **44** also can be designed to exercise control over the opening and closing of valves **56**.

Referring generally to FIG. **2**, a flow chart is provided to illustrate one embodiment of a procedure utilizing packer assembly **20**. In this example, inflatable packer **24** is initially moved to a desired sample depth in wellbore **22**, as indicated by block **60**. The sensors **40**, e.g. extensometers **46**, are then used to measure hole ovality, as illustrated by block **62**. Subsequently, packer **24** is fully inflated and the contact pressure with the surrounding wellbore wall is monitored via embedded pressure sensors **42**, as indicated by block **64**. The sensors **40**, e.g. fluid property sensors **48**, also can be used to verify individual sealing of the sample drains **32** and the guard drains **34**, as indicated by block **66**.

Once the inflatable packer **24** is properly positioned in the wellbore and sufficient sealing is verified, the sampling procedure begins, as illustrated by block **68**. During the sampling procedure, the fluid properties and drain sealing may be monitored by appropriate sensors **40**, as illustrated by block **70**. Subsequently, the sampling procedure is completed, as indicated by block **72**, and the packer **24** is deflated, as indicated by block **74**. The sensors **40**, e.g. extensometers **46**, can again provide data to data acquisition system **44** to verify packer deflation, as indicated by block **76**. Upon deflation, the packer **24** may be moved to the next sampling location, and the procedure may be repeated.

Depending on the specific application and environment, various procedural steps can be added, removed, and/or expanded. Furthermore, data acquisition system **44** can be programmed to utilize sensor data according to a variety of paradigms. As illustrated in FIG. **3**, for example, measurement of hole ovality may be tested and used to determine placement of the inflatable packer **24**. In this example, the measurement of hole ovality is accomplished by inflating packer **24** until contact pressure sensors **42** indicate contact with the surrounding wall, as indicated by block **78**. Additionally, data obtained from extensometers **46** can be used as an indicator of the degree of expansion at packer ends and/or other locations along packer **24**. As described in greater detail below, the extensometers **46** may be designed and positioned to measure rotation of S-shaped connector flow lines. The data from the various sensors **40** is processed by data acquisition system **44** to determine whether the hole ovality is acceptable, as indicated by block **80**. If no, the packer **24** is moved to a different location and depth, as indicated by block **82**. If yes, the process can proceed to the next stage and the sampling procedure can be continued, as indicated by block **84**.

Similarly, the procedural stage involving completion of inflation and monitoring of contact pressure also may utilize output from various sensors **40**, as illustrated by the flowchart of FIG. **4**. In this example inflation pressure is initially increased to a minimum working pressure, as indicated by block **86**. Contact pressure sensors **42** are used to monitor local contact pressures, as indicated by block **88**, and the contact pressure data is provided to data acquisition unit **44**. The data acquisition unit is used to determine whether contact pressure is evenly distributed, as indicated by block **90**. If the pressure is sufficiently evenly distributed, the process can proceed to the next stage and the overall sampling procedure can be continued, as indicated by block **92**. However, if the contact pressure is not evenly distributed, then the inflation pressure of packer **24** is increased to a maximum working pressure, as indicated by block **94**. If this action results in sufficiently evenly distributed contact pressure, the process can proceed to the next stage, as indicated by block **96**. If, however, the data does not indicate an evenly distributed contact pressure, additional corrective action can be taken, as indicated by block **98**. For example, the packer **24** can be reinflated at a different location or one or more of the drains **30** can be mechanically isolated.

The verification of sealing with respect to individual sample drains and guard drains also may comprise additional procedural steps and utilization of sensor data, as illustrated by the flowchart of FIG. **5**. In this example, the isolation of an individual drain, e.g. a sample drain **32**, is initially tested, as indicated by block **100**. A drawdown of pressure is applied to the selected drain, as indicated by block **102**. The pressure in the isolated drain is monitored via an appropriate sensor, e.g. the fluid property sensor **48** in the subject drain, as illustrated by block **104**. The sensor data is supplied to data acquisition system **44** which processes the data to determine whether the seal integrity is sufficient for the subject drain, as indicated by block **106**.

If the seal integrity is sufficient, the sealing verification stages are repeated for each of the remaining drains, as indicated by block **108**, until the verification process is completed and the overall sampling process can be moved to the next stage, as indicated by block **110**. If the seal integrity of a given drain is not sufficient, the inflation pressure of packer **24** can be increased to a maximum working pressure, as indicated by block **112**. Assuming the increased pressure results in sufficient seal integrity, the stages can be repeated for the other drains. However, if the action does not result in sufficient seal integrity additional corrective action can be taken, as indicated by block **114**. For example, the packer **24** can be reinflated at a different location or one or more of the drains **30** can be mechanically isolated.

The monitoring of fluid properties and drain sealing following initiation of the sampling procedure also may comprise additional procedural steps and utilization of sensor data, as illustrated by the flowchart of FIG. **6**. In this example, data from fluid property sensors **48** positioned in individual drains **30** or at other suitable locations provides data indicative as to whether the seal integrity is sufficient for an individual drain, as represented by block **116**. If the seal integrity is sufficient for the individual drain, the process can be repeated for the remaining drains as indicated by block **118**. However, if the seal integrity of a given drain is not sufficient, the inflation pressure of packer **24** can be increased to a maximum working pressure, as indicated by block **120**. Assuming the increased pressure results in sufficient seal integrity, the procedural stages can be repeated for the other drains. However, if the action does not result in sufficient seal integrity additional corrective action may be taken, as indicated by block **122**. For example, the packer **24** can be reinflated at a different location or one or more of the drains **30** can be mechanically isolated.

Once the seal integrity for each of the drains is addressed, the fluid flow rate through each drain is detected by an appropriate sensor **40**, e.g. flow meter **54**, as indicated by block **124**. If the flow rate is sufficient for the drains, the fluid properties from the fluid collected through each drain are monitored, as indicated by block **126**. However, if the flow rate data indicates a clogged drain, the drain can be isolated by closing the associated valve **56**, as indicated by block **128**. In the event a clogged drain is corrected, the monitoring of fluid properties for the drain can be commenced once again. However, if the drain is not unclogged additional corrective action may be taken, as indicated by block **130**. For example, the packer **24** can be deflated and fluid can be reversed pumped through the packer to clear the drain obstruction.

After the flow rates for the drains are addressed, the fluid resistivity can be checked for each sample drain **32** via, for example, resistivity sensors **52**, as indicated by block **132**. If the resistivity is indicative of the desired fluid flow, the pumping of sample fluid is continued until the sampling operation is completed, as indicated by block **134**. Subsequently, the overall sampling process may be moved to the next stage, as indicated by block **136**. In the event the resistivity data indicates the presence of an unwanted fluid, such as water, corrective action may be taken, as indicated by block **138**. For example, the sample drain producing water can be isolated by adjusting the appropriate valve.

The verification of packer deflation upon completion of a sampling procedure also may comprise additional procedural steps and utilization of sensor data, as illustrated by the flowchart of FIG. **7**. In this example, retraction of the packer **24** is verified by monitoring data output from suitable sensors **40**, such as data output from extensometers **46**, as indicated by block **140**. For example, the extensometers **46** can be designed and positioned to measure rotation of S-shaped connector flow lines, which rotation is indicative of the degree of packer expansion. Data from the sensors **40** is provided to data acquisition system **44** to determine whether the packer retraction is acceptable, as indicated by block **142**. If the packer retraction is acceptable, packer **24** may be moved to a new sample location at a different sample depth, as indicated by block **144**. However, if the packer retraction is not acceptable, the packer is held at a deflated state, and a retraction tool or system can be used to reduce the outside diameter of the packer **24**, as indicated by block **146**.

The procedural examples illustrated and described above are just a few of the many procedural approaches that can be used in utilizing sensor system **38** and in obtaining fluid samples with single packer **24** in a variety of well environments. Similarly, the size, shape and configuration of packer **24** may vary depending on the specific sampling applications and environments.

One embodiment of a specific single packer design is illustrated in FIG. **8**. In this example, packer **24** is a single packer having an outer layer formed as outer flexible skin **26** made of an elastic material, e.g. rubber. The outer flexible skin **26** is expandable in a wellbore to seal with a surrounding wellbore wall. The single packer **24** comprises an inner inflatable bladder **148** disposed within outer flexible skin **26**. By way of example, the inner bladder **148** may be selectively expanded by introducing fluid via the interior packer mandrel **28**. Additionally, the packer **24** comprises a pair of mechanical fittings **150** that may comprise fluid collectors **152** coupled with flow lines **36**. The mechanical fittings **150** are mounted around inner mandrel **28** and engaged with axial ends of outer flexible skin **26**.

With additional reference to FIG. **9**, the outer flexible skin **26** comprises openings for receiving drains **30** through which formation fluid is collected when the outer flexible skin is expanded against a surrounding wellbore wall. The drains **30** may be embedded radially into the outer flexible skin **26**, and a plurality of the flow lines **36** may be operatively coupled with drains **30** for directing the collected formation fluid in an axial direction to one or both of the mechanical fittings **150**. According to one embodiment, the flow lines **36** are in the form of tubes, and separate tubes are connected to the guard drains **34** and the sample drains **32** disposed between the guard drains. The separate tubes maintain separation between the fluids flowing into the guard drains and the sample drains, respectively.

As illustrated in FIG. **9**, the flow line tubes **36** may be oriented generally axially along packer **24**. The flow lines **36** extend through the axial ends of outer flexible skin **26**. By way of example, flow line tubes **36** may be at least partially embedded in the flexible material of outer flexible skin **26**. Consequently, the portions of flow lines **36** extending along outer flexible skin **26** move radially outward and radially inward during expansion and contraction of packer **24**.

Referring generally to FIG. **10**, one embodiment of mechanical fittings **150** comprises the collector portion **152** coupled with a plurality of movable members **154**. The movable members **154** are pivotably coupled to each collector portion **152** via pivot links for pivotable motion about an axis generally parallel with the packer axis. At least some of the movable members **154** are designed as tubes to transfer fluid received from the flow lines **36**, extending along outer flexible skin **26**, to collector portions **152**. From collector portions **152**, the collected fluids may be transferred/directed to desired collection/testing locations. The pivotable motion of movable members **154** enable transition of packer **24** between the contracted state, illustrated in FIG. **10**, and the expanded state illustrated in FIG. **11**. As illustrated best in FIG. **11**, the movable members **154** may be designed generally as

S-shaped members pivotably connected between flow lines in outer flexible skin **26** and collector portions **152**.

In this particular embodiment of inflatable packer **24**, extensometers **46** are designed as rotational sensors positioned to engage and measure rotation of select movable members **154**. (See FIG. **11**). By measuring the rotation angle of one or more movable members **154** and outputting the data to data acquisition system **44**, the degree of expansion or contraction of packer **24** can be determined. Monitoring the rotation angle also enables determination of an average borehole diameter. This information is useful for quality control by facilitating detection of a damaged zone, proper inflation of packers, proper choice of downhole tools, and other operational factors.

The expansion ratio of the packer also is useful in providing a more accurate measurement of the borehole dimensions and its irregularities that can result from washouts and/or distorted ovality. The packer can effectively be used as a caliper tool which also is helpful in evaluating the wellbore. For example, by obtaining data on well ovalization, packer pressurization can be optimized to ensure sealing. In some types of packers, e.g. cable packers, the packer can experience weakening when inflated in oval wells. Consequently, data collected on wellbore ovalization is useful in ensuring that inflation pressure does not break an inner bladder of the packer. The measurement of packer outside diameter also is useful when the packer **24** is deflated. By knowing the degree of deflation, an operator can determine whether extraction of the packer is possible and whether retraction mechanisms, e.g. auto retract mechanisms, are operating efficiently.

As illustrated in FIG. **12**, this particular embodiment of inflatable packer **24** is amenable for use with a variety of the sensors **40** discussed above. As illustrated, sensors **42** can be embedded into outer flexible skin **26** to measure contact pressure or other parameters related to actuation of packer **24**. Embedded sensors also could be used to detect parameters related to the well environment, e.g. fluid properties. Additional sensors **40**, such as fluid property sensors **48**, can be mounted in some or all of the drains **30**. Alternatively or in addition, fluid property sensors **48** may be mounted in collector portions **152**, as further illustrated in FIG. **12**. The illustrated sensors may be interchanged with other sensors, and additional sensors can be added. For example, pressure gauges, flow meters, density meters, viscosity meters, resistivity meters, and other sensors can be mounted along packer **24**, as discussed above.

Furthermore, valves **56** may be mounted in desired locations along flow lines **36**, as illustrated in the example of FIG. **13**. Individual valves **56** may be controlled by the data acquisition/control system **44** to control the flow of fluid along individual flow lines **36**. The control over flow enables an operator to, for example, isolate specific drains **30** if a sufficient seal is not formed around the drain or if other problems arise with respect to a given drain or drains.

The sensors **40** provide an instrumented packer **24** that may be selectively expanded, e.g. inflated, in a wellbore, as illustrated by FIG. **14**. Once packer **24** is inflated, sensors **48** within drains **30** are placed in proximity with the surrounding formation **156** to facilitate detection and measurement of a variety of well related parameters, including fluid parameters. Other sensors can be used to detect additional well related parameters and/or to detect parameters related to actuation of the packer **24**. For example, sensor data can be provided to data acquisition system **44** and used in determining whether the packer **24** has been adequately expanded or retracted and whether sufficient seals have been formed with the surrounding wellbore wall.

Also, in any of the embodiments described above where a component is described as being formed of rubber or comprising rubber, the rubber may include an oil resistant rubber, such as NBR (Nitrile Butadiene Rubber), HNBR (Hydrogenated Nitrile Butadiene Rubber) and/or FKM (Fluoroelastomers). In a specific example, the rubber may be a high percentage acrylonytrile HNBR rubber, such as an HNBR rubber having a percentage of acrylonytrile in the range of approximately 21 to approximately 49%. Components suitable for the rubbers described in this paragraph include, but are not limited to, outer flexible skin **26** and inflatable bladder **148**.

As described above, packer assembly **20** may be constructed in a variety of configurations for use in many environments and applications. The packer **24** may be constructed from different types of materials and components for collection of formation fluids from single or multiple intervals within a single expansion zone. The flexibility of the outer flexible skin enables use of packer **24** in many well environments. Additionally, the various sensors and sensor arrangements may be used to detect and monitor many types of parameters that facilitate numerous procedures related to the overall sampling operation. Furthermore, the various packer components can be constructed from a variety of materials and in a variety of configurations as desired for specific applications and environments.

Accordingly, although only a few embodiments of the present invention have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this invention. Such modifications are intended to be included within the scope of this invention as defined in the claims.

What is claimed is:

1. An apparatus for use in a wellbore comprising:

an expandable packer assembly inflatable to seal against a wall of the wellbore, comprising:

an opening in the expandable packer assembly for receiving fluid into the expandable packer assembly from the wellbore or a formation about the wellbore;

a flowline connected to the opening for moving the fluid into the packer assembly, the flowline having at least a portion movable radially outward and radially inward during inflation and contraction of the packer assembly; and

a sensor within the portion of the flowline for measuring movement of the flowline, wherein the portion of the flowline rotates as the packer assembly expands, and further wherein the sensor measures the rotation of the portion of the flowline to indicate an amount of the inflation of the packer assembly.

2. The apparatus of claim **1** wherein the sensor is an extensometer.

3. The apparatus of claim **1** further comprising an outer skin layer inflatable to expand the packer assembly, wherein the opening is formed in the outer skin layer.

4. The apparatus of claim **1** wherein the sensor is further capable of measuring a temperature of fluid received in the opening.

5. The apparatus of claim **1** further comprising a data acquisition unit in communication with the sensor to determine an expansion ratio of the packer assembly.

6. The apparatus of claim **1** where the portion of the flowline is s-shaped.

7. A method comprising:

deploying a packer assembly into a wellbore, the packer assembly inflatable toward a wall of the wellbore, the packer assembly having an opening connected to a flowline for receiving fluid and a first sensor on or within the flowline;

moving the flowline while inflating the packer assembly toward the wall of the wellbore; and

measuring movement of the flowline with the first sensor; and

determining a parameter related to inflation or contraction of the packer assembly based on the measurement of the movement of the flowline, wherein moving the flowline while inflating the packer assembly comprises rotating the flowline and further wherein the first sensor measures a rotation angle of the flowline.

8. The method of claim **7** further comprising controlling inflation of the packer assembly based on the measurement of the flowline.

9. The method of claim **7** wherein the step of determining a parameter related to inflation or contraction comprises determining an expansion ratio of the packer assembly.

10. The method of claim **7** wherein the first sensor determines a property of the fluid within the flowline.

11. The method of claim **7** further comprising determining contact pressure with the wall of the wellbore with a second sensor positioned adjacent the opening.

12. The method of claim **7** further comprising measuring a temperature of the fluid in the flowline or a temperature of an outer skin of the packer assembly with a second sensor or the first sensor.

13. The method of claim **7** further comprising measuring a property of the fluid with a second sensor or the first sensor in the flowline.

14. The method of claim **7** further comprising communicating with a data acquisition system to determine the parameter related to inflation or contraction of the packer assembly based on the measurement of the movement of the flowline.

15. The method of claim **7** further comprising determining contact pressure with wall of the wellbore with a second sensor positioned adjacent the opening, and comparing pressure at the second sensor to a predicted pressure.

16. The method of claim **15** wherein the opening is closed based on the comparison of the contact pressure and the predicted pressure.

17. The method of claim **7** further comprising utilizing the first sensor to optimize inflation pressure of the packer assembly.

* * * * *